



Figure 1. National parks and permafrost monitoring sites. Yellow dots indicate Permafrost/Active Layer Monitoring Program borehole locations. Red lines show snowmobile trip routes for borehole installation and community outreach. NPS units are shown in blue.

# Permafrost/Active Layer Monitoring Program: Involving Remote Villages in Permafrost Drilling for Operational and Scientific Applications in Alaska

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## Overview

The Permafrost/Active Layer Monitoring Program is an ongoing project which builds on work begun in 2005 to establish long-term permafrost and active layer monitoring sites adjacent to schools in Alaska and in the circumpolar permafrost region. Monitoring stations in Alaska are located in communities near national parks and their headquarters, such as Kotzebue, Nome, Fairbanks, Eagle, Circle, Northway, Glennallen, Healy, Cantwell, Anaktuvuk Pass, Noatak, Shishmaref, Ambler, Kiana, and Igiugig. Currently, there are 120 schools in Alaska involved in the project including also Denali National Park and Preserve. The project has both a scientific and outreach component. The monitoring sites collect temperature data on permafrost and the length and depth of the active layer (the layer above the permafrost that thaws during summer and freezes again during winter).

Most of the monitoring sites are located in remote communities, where the majority of residents depend on a subsistence lifestyle. Changes in climate, length of seasons, and permafrost conditions directly impact natural resources

and subsistence activities. Changes in permafrost conditions also affect local ecosystems and hydrological regimes, and can influence the severity of natural disasters. In addition to extending our knowledge of the arctic environment, the program involves school-age students in hopes of inspiring a new generation of scientists to continue this study.

The data gathered from these stations are shared with other schools and made available to the public through our web site (<http://www.uaf.edu/permafrost>). The data contribute to several widely used science databases, including the permanent archive at the National Snow and Ice Data Center in Boulder, Colorado. In addition to working with local borehole data, teachers can compare their data with that from other participating schools at the website. Through this project, students in remote communities learn more about science in a way that is meaningful to their daily lives. In addition, they experience research participation within a larger scientific community, expanding their worldview. This project involves more than 10,000 students and 500 teachers across Alaska.

As part of this project, specialists in outreach education are developing a

classroom lesson unit, Permafrost/Active Layer in Alaska, which will be included in a movie series titled "Tunnel Man."

## The Science

Permafrost regions occupy about one-quarter of Earth's land surface. Permafrost is one of the most important components of the arctic terrestrial system, and this physical element of the landscape is one of the most sensitive to climatic change. Therefore, observing the interactions between permafrost and other components of the arctic system (climate, hydrology, biogeochemistry, vegetation), especially during a period of possible climatic warming, is among the most important aspects of arctic research. The changing properties of permafrost play an important role in driving the ecosystem balance, as well as affecting carbon and water cycles (*Oechel et al. 2000*). Additionally, man-made structures built on or near ice-rich permafrost can suffer severe damage from thaw-induced ground settling, which will accelerate if mean annual temperatures continue to rise (*Osterkamp et al. 2000, Romanovsky and Osterkamp 2001*).

Within the sensitive permafrost region, the discontinuous permafrost zone

**Figure 2. (Left) Traveling by snowmobile to Anvik during Iditarod race, about 900 miles in spring 2007, hauling gear and equipment for the research.**

Photograph courtesy of K. Yoshikawa



Photograph courtesy of K. Yoshikawa

**Figure 3. Ice exposed at Marshall on the Yukon River, March 2007.**

COUNTRY	REGION	PERMAFROST TEMPERATURE TRENDS	REFERENCE
USA	Trans-Alaska pipeline route (20 m), 1983–2000	+0.6 to +1.5°C	Romanovsky and Osterkamp 2001
	Barrow Permafrost Observatory (15 m), 1950–2001	+1°C	Our ongoing research
Russia	East Siberia (1.6–3.2 m), 1960–1992	+0.03°C/year	Our ongoing research
	North of West Siberia (10 m), 1980–1990	+0.3 to +0.7°C	Pavlov 1994
	European North of Russia, continuous permafrost zone (6 m), 1973–1992	+1.6 to +2.8°C	Pavlov 1994
Canada	Northern Mackenzie basin (28 m), 1990–2000	+0.1°C/year	GSC data
	Central Mackenzie basin (15 m), 1985–2000	+0.03°C/year	GSC data
	Alert (15 m), 1995–2000	+0.15°C/year	Geological Survey of Canada (GSC) data

**Figure 4. Recent trends in permafrost temperatures measured at different locations (Romanovsky et al. 2002).**

is the most likely to respond to climatic warming. Most national parks in Alaska are located in this zone. Throughout the circumpolar North, the boreal forest widely overlaps the area of discontinuous permafrost (Péwé 1975). Thermal conditions of discontinuous permafrost are quite unstable, as the ground is close to thawing, with temperatures often hovering at 30°F (-1°C) or warmer.

The table in Figure 4 is an overview of the principal permafrost monitoring programs in the circumpolar North, with major findings and results summarized. Most notable is the evidence of a warming trend, even with few permafrost

monitoring sites.

For maintenance purposes and educational outreach, the majority of our monitoring sites are located at or near schools or national park headquarters (Figure 1). This allows easier accessibility to equipment, provides educational opportunities by involving students and teachers in research, and facilitates data collection.

### Classroom Activities and Lessons

The classroom activities developed for the Permafrost/Active Layer Monitoring Program are differentiated by age group. The program offers teachers unique opportunities to integrate research and

education by offering students a chance to work with and learn from experienced permafrost scientists; provides classroom lessons on permafrost and the active layer, an important part of Alaskan geoscience; and distributes by DVD and Internet an entertaining educational movie series called “Tunnel Man.” Educational activities include the following:

(1) To help students understand permafrost and its impact on the environment, permafrost monitoring sites are established and boreholes are drilled. Scientists introduce the project and guide student discussion, focusing on the question, “Why do we need to monitor permafrost?”

(2) To demonstrate scientific methodology, design, and fieldwork, frost tubes are installed, data loggers are set up, and scientists calibrate temperature sensors with assistance from students. Students and teachers explore the following questions with scientists’ guidance: “What kind of sensors and instruments are we using?” and “How do these instruments work for us?” We provide teachers with a set of classroom lessons (Figures 5).

(3) About a year later, during the scientists’ return visit, a second set of lessons is developed in partnership with the teachers and is used to explore the temperature data. After one year of data collection, students use the data to investigate permafrost and frozen ground, climate change impact on permafrost stability, and methods of monitoring changes in permafrost. Teachers download the data and use an Excel spreadsheet to plot monthly profiles, calculate

the average temperature for each depth, and estimate active layer thickness. At this point, students focus on the following questions: “What is going on in our village?” and “What is most likely to happen in the future in our village?” (Figures 6–7).

(4) A model predicting changes in local permafrost is developed and used by students in the classroom. Students share data, comparing their data with that from different areas all over the world. Our hope is that by this point students will understand many of the issues related to permafrost and how it affects the world around them. Teachers supplement the curriculum with an entertaining and instructional movie, “Tunnel Man.”

(5) For the upper grades and national park visitors, more advanced classroom lectures and demonstrations are available, which offer opportunities for a more complex understanding of the interactions between permafrost and climate change. One example of the effects of natural phenomena is the impact of forest (or tundra) fires on permafrost. Fire has a strong impact on permafrost degradation; fires burn away the insulation layer, which changes the thermal condition of the permafrost. Students measure and simulate the impact that wildfires of varying severity can have on permafrost.

### Summary

The intellectual merit of this research is that it will advance knowledge of our climatic system and the thermal state of permafrost as a complex pro-

cess that is spatially and temporally quite variable. The arctic climatic system has an important influence on global climate. Monitoring the thermal state of permafrost by measuring borehole temperatures is one of the methods that can be used to understand climatic trends. The degradation of permafrost is triggered by the length of the active layer freezing period; that is, seasonal lengths are an important factor. Implicit in many climatic change reports is the desire to develop a sustainable scientific infrastructure to address needs, among which is the establishment and maintenance of long-term observational networks. The Permafrost/Active Layer Monitoring Program provides opportunities for field experience and educational participation at levels ranging from elementary school to high school. It will help to provide high-resolution spatial distribution of the thermal state of permafrost, especially in Alaska, and will improve the general knowledge of Earth's climatic pattern. It also offers an opportunity for students to take part in understanding climatic systems. This project highlights the interaction between permafrost, the active layer, hydrology, and the arctic climate system, and provides a strong educational outreach program involving remote communities.



Figure 5. Students watch borehole installation (left) and experience communicating with the data logger via laptop computer (right).



Figure 6. Students measure active layer depth (left) and look at physical details of frozen soil composition (right).

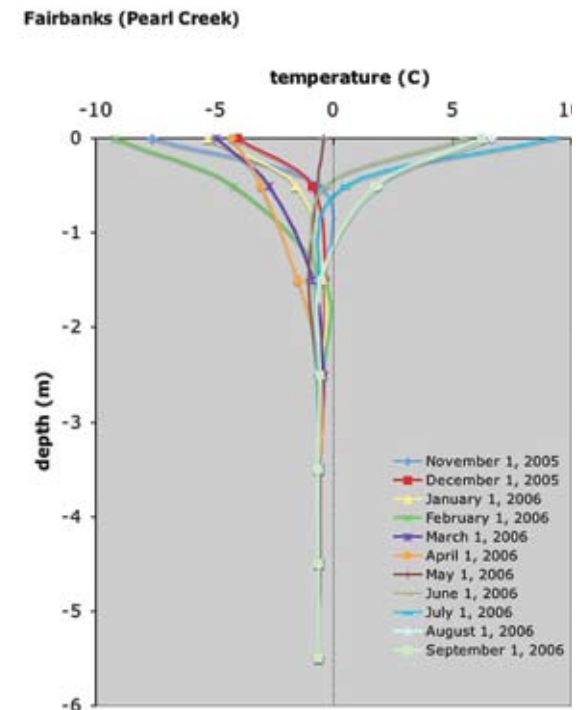


Figure 7. Demonstrating for students the seasonal variations of ground temperature using obtained data.

## REFERENCES

Oechel, W.C., G.L. Vourlitis, S.J. Hastings, R.C. Zulueta, L.D. Hinzman, and D.L. Kane. 2000.

*Acclimation of ecosystem CO<sub>2</sub> exchange in the Alaskan Arctic in response to decadal climate warming.* Nature 406: 978-981.

Osterkamp, T.E., L. Viereck, Y. Shur, M.T. Jorgenson, C. Racine, A. Doyle, and R.D. Boone. 2000.

*Observations of thermokarst and its impact on boreal forests in Alaska, USA.* Arctic, Antarctic, and Alpine Research 32: 303-315.

Pavlov, A.V. 1994.

*Current changes of climate and permafrost in the Arctic and Sub-Arctic of Russia.* Permafrost and Periglacial Processes 5: 101-110.

Péwé, T.L. 1975.

*Quaternary Geology of Alaska.* US Geological Survey Professional Paper 835.

Romanovsky, V.E., and T.E. Osterkamp. 2001.

*Permafrost: Changes and impacts.* In: *Permafrost Response on Economic Development, Environmental Security and Natural Resources*, edited by R. Paepe and V. Melnikov. Kluwer Academic Publishers. Pages 297-315.

Romanovsky, V., M. Burgess, S. Smith, K. Yoshikawa, and J. Brown. 2002.

*Permafrost temperature records: Indicators of climate change.* EOS, AGU Transactions 83(50): 589-594.